Jet reconstruction and jet background classification with the ALICE experiment in Pb-Pb collisions at the LHC

C Klein-Bösing[1,2] for the ALICE Collaboration ‡

[1] Institut für Kernphysik - Münster, Germany

[2] ExtreMe Matter Institute, GSI - Darmstadt, Germany

E-mail: `Christian.Klein-Boesing@uni-muenster.de`

Abstract. For a quantitative interpretation of reconstructed jet properties in heavy-ion collisions it is paramount to characterize the contribution from the underlying event and the influence of background fluctuations on the jet signal. In addition to the pure number fluctuations, region-to-region correlated background within one event can enhance or deplete locally the level of background and modify the jet energy. We show a first detailed assessment of background effects using different probes embedded into heavy-ion data and quantify their influence on the reconstructed jet spectrum.

1. Introduction

The quantification of the effect of parton energy loss, known as jet quenching, is one of the major goals of jet and high $p_{\rm t}$ measurements in heavy-ion collisions. The aim of jet reconstruction is to gain more direct access to the orignal parton properties and the modification of their fragmentation process in heavy-ion collisions than single particle measurements [1, 2]. Already the first measurements of reconstructed jets in heavy-ion collisions at the LHC showed a striking imbalance between back-to-back dijets [3] pointing to a significant partonic energy loss in the medium. However, a quantitative interpretation of any jet result requires a precise knowledge of the background-induced fluctuations of the measured jet signal, which can distort the jet balance even in the absence of any other medium effects [4].

2. Jet Reconstruction and Background Subtraction

The data presented here were collected by the ALICE experiment [5] in the first Pb-Pb run of the LHC in the fall of 2010 with an energy of $\sqrt{s_{\rm NN}} = 2.76$ TeV. Since the Electromagnetic Calorimeter (EMCal) has only been fully installed since the beginning of 2011, jets from the first Pb-Pb and pp collisions in ALICE are reconstructed based

‡ For the full ALICE Collaboration author list and acknowledgments, see Appendix "Collaborations" of this volume.

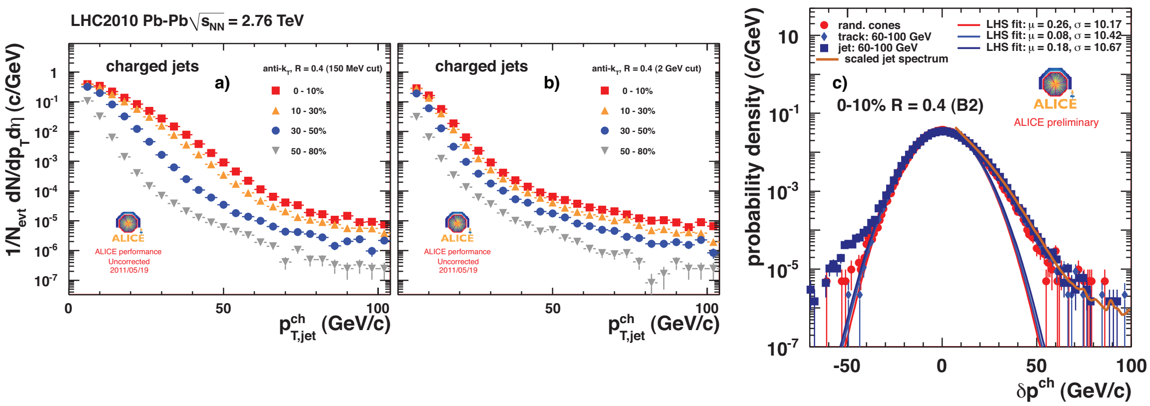

Figure 1. Reconstructed raw jet spectra for different centralities using the anti-k_t algorithm after background subtraction: a) track $p_t > 150$ MeV/c b) track $p_t > 2$ GeV/c. c) δp_t distribution of charged particles in the 10% most central Pb-Pb events for different probes together with scaled jet spectrum (p_t cut of 150 MeV/c).

on charged particles only. For this we use tracks reconstructed in the Time-Projection-Chamber (TPC) together with vertexing information from the Inner Tracking System (ITS). This ensures maximum azimuthal angle (ϕ) uniformity of reconstructed tracks with transverse momenta down to $p_t = 150$ MeV/c.

We employ a variety of jet finders, which exhibit different sensitivities to the presence of large backgrounds in heavy-ion collisions and show good agreement above $p_t = 20$ GeV/c in pp-collisions [7]; cone algorithms (UA1 and SISCone), as well as the sequential recombination algorithms from the FastJet package (k_t and anti-k_t [6]), all with a distance/radius parameter of 0.4. Here, the k_t algorithm is used to estimate the background density ρ on an event-by-event basis by calculating the median p_t/area of reconstructed k_t-clusters in $\eta < 0.5$ after removing the two leading clusters (see also [8]). For the present study we focus on jets that are reconstructed using the anti-k_t algorithm and corrected for the background density in each event using the jet area A with $p_t^{\rm jet} = p_t^{\rm jet,rec} - \rho \cdot A$.

The resulting raw jet spectra are shown in figure 1a) and b) for different values of the minimum track p_t. The difference in the shape for central reactions and the low p_t track cut is clearly visible, showing the dominance of background fluctuations over a wide p_t-range.

3. Background Fluctuations

Background fluctuations are determined using different probes of the measured Pb-Pb collisions: random cones ($R = 0.4$) placed into the jet acceptance, where the p_t of all tracks in the cone is summed, embedding of single high p_t tracks, and embedding of full pp jet events (real or from full detector simulation). In case of embedding the standard anti-k_t algorithm with $R = 0.4$ is used to cluster the event and the reconstructed jets are matched to the embedded probe, by either finding the single track in it, or 50% of

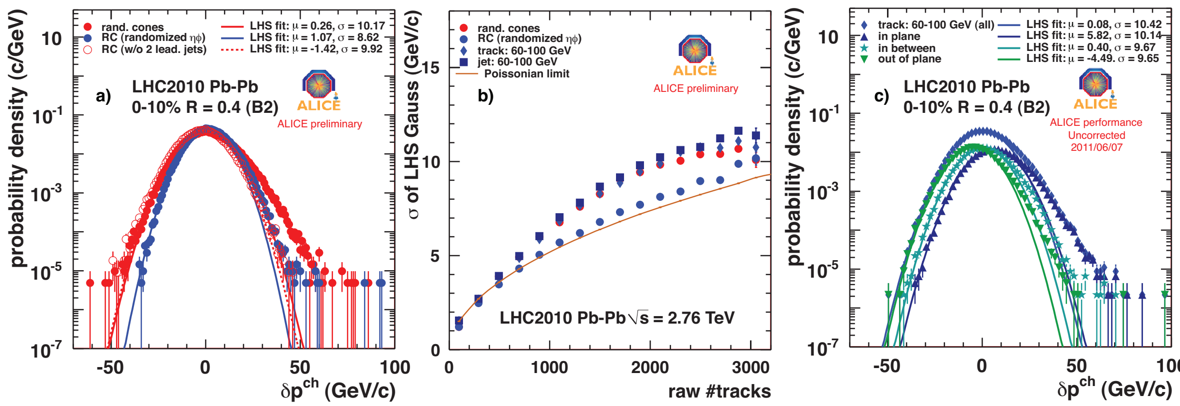

Figure 2. δp_{t} distribution of charged particles in the 10% most central Pb-Pb events for a) random cones (RC) on full events, requiring a minimum distance to the two leading jets, and on randomized events c) for single tracks for different orientations to the event plane. b) Evolution of background fluctuations with input multiplicity and compared to the Poissonian limit derived from the measured track p_{t} spectrum.

the pp jet momentum (in the case of jet embedding). The residuals of the background subtraction are then given by:

$$\delta p_{\mathrm{t}} = p_{\mathrm{t}}^{\mathrm{rec}} - A \cdot \rho - p_{\mathrm{t}}^{\mathrm{probe}} \tag{1}$$

(where $p_{\mathrm{t}}^{\mathrm{probe}}$ is zero in the case of random cones). The resulting distributions are shown in figure 1c). The distribution is peaked around zero, illustrating the validity of the background subtraction. We iteratively fit the left-hand-side of each distribution with a Gaussian to obtain a measure for the width of the distribution. The σ of the Gaussian fit provides the lower limit on the total fluctuations and is larger than 10 GeV/c for all methods. The deviation from the Gaussian shape on the right-hand-side of the distribution is apparent, and is also reflected in the RMS of the full distributions which ranges from 11.4 to 12 GeV/c. It can be explained mainly by the presence of jets in the Pb-Pb events used for embedding, as seen by the shape of the scaled reconstructed jet spectrum. It is also seen in figure 2a), where the δp_{t} distribution from random cones on full events is compared to random cones with a minimum distance to the leading jets and in events where the tracks have been randomized in η and ϕ. In the latter two cases the tail attributed to jets is much less pronounced and a Gaussian shape is almost recovered. It has to be noted that the distributions due to purely statistical fluctuations are not expected to exactly follow a Gaussian shape, but instead are better described by a Γ-function [9], since δp_{t} is similar to a measurement of $\langle p_{\mathrm{t}} \rangle$ fluctuations in a limited region of phase space. The removal of the jet contribution does not affect the left side of the distribution, it only becomes narrower if all residual correlations are destroyed by randomizing the event, this points to correlated region-to-region fluctuations in addition to the purely statistical.

The contribution of statistical fluctuations to the overall fluctuations of the underlying event within a typical jet cone can be seen in figure 2b), where the Poissonian

limit estimated via:

$$\mathrm{RMS}(\delta p_{\mathrm{t}}) = \sqrt{N_{\mathrm{A}}} \cdot \sqrt{\langle p_{\mathrm{t}} \rangle^2 + \mathrm{RMS}(p_{\mathrm{t}})^2} \tag{2}$$

is compared to the measured fluctuations for different input multiplicities. Here, N_{A} is the total uncorrected input multiplicity scaled to the jet area. The values are taken from the uncorrected track p_{t} spectrum used for jet finding. For ideal track detection the statistical fluctuations in a typical jet cone would increase by 8%, using the values from the efficiency and acceptance corrected track p_{t} spectrum. The $\sqrt{N}$ increase is clearly seen in all cases, but only for randomized events the limit is approached, with large differences especially at intermediate multiplicities.

One natural source of region-to-region differences is the presence of collective effects (flow) in the underlying event. This can be visualized when dividing the embedded probes into different bins, depending on their orientation to the event plane. In figure 2c) it can be clearly seen that for probes embedded out of plane the background is overestimated by almost 5 GeV/c, for in plane the effect is opposite. Since within the jet we sum over all particle p_{t} the effect scales with $\sum v_2(p_{\mathrm{t}})p_{\mathrm{t}}$ and thus is still sizable in central events. The separation of collective effects from jet-induced region-to-region fluctuations will be a challenge for any jet measurement at lower p_{t} and with low momentum cut-off, but is essential for the understanding of the modification of jet fragmentation at low track p_{t} and its path-length dependence.

4. Summary

We have presented the first detailed study of background fluctuations for jet reconstruction in Pb-Pb collisions at the LHC, where we observe for charged particle jet reconstruction and a low p_{t} cut-off of 150 MeV/c jet background fluctuations larger than 10 GeV/c in central collisions and for a typical distance parameter/radius of 0.4. The fluctuations show a significant increase compared to purely statistical fluctuations, which is caused by correlated region-to-region fluctuations. In particular the presence of collective effects (flow) can induce shifts in the background subtracted jet p_{t} of up to 5 GeV/c.

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